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INITIAL SOFTWARF FOR EMPASS EP-3A DIGITAL SYSTEM

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FOREWORD

The work reported herein was accomplished as part of the Electromagnetic Performance of Air and Ship Systems Project at the Naval Surface Weapons Center, Dahlgren Laboratory. The task was performed in the Systems Development Branch, Electromagnetic Systems Division, Advanced Systems Department.

A special acknowledgement is made to Mr. E. R. Whalen for his guidance in the design of this system and for his leadership in the establishment of a ground-based laboratory for software development.

This report was reviewed and approved by:

L. M. Woodward, Head, Systems Development Branch, Electromagnetic Systems Division

R. L. Schmidt, Head, Electromagnetic Systems Division

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Advanced Systems Department

ABSTRACT

A digital system developed to support the Electromagnetic Performance of Air and Ship Systems (EMPASS) Project at NSWC/DL is reported. The airborne system consists of RF receivers and antennas with special relays and interface units which allow a UNIVAC 1830A computer to interrogate and control them. Aircraft position, RF signal, and system status measurements are recorded digitally on magnetic tape while operator displays are provided for some immediate data analysis and system monitoring. The software for this data acquisition system was designed and developed at NSWC/DL and is currently being used on test and measurement missions of the EMPASS aircraft.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

The Naval Surface Weapons Center, Dahlgren Laboratory (NSWC/DL), in its Electromagnetic Performance of Air and Ship Systems (EMPASS) Project, has developed an airborne measurement system to evaluate the electromagnetic performance of the Navy's airborne, shipboard, and ground-based systems in their operating environment. A UNIVAC 1830A computer interrogates and controls RF receivers and antennas through special interface units to digitally record aircraft position, RF signal, and system status information (Figure 1). The CDC 6700 computer system is utilized for analyzing the recorded data and producing graphical test results.

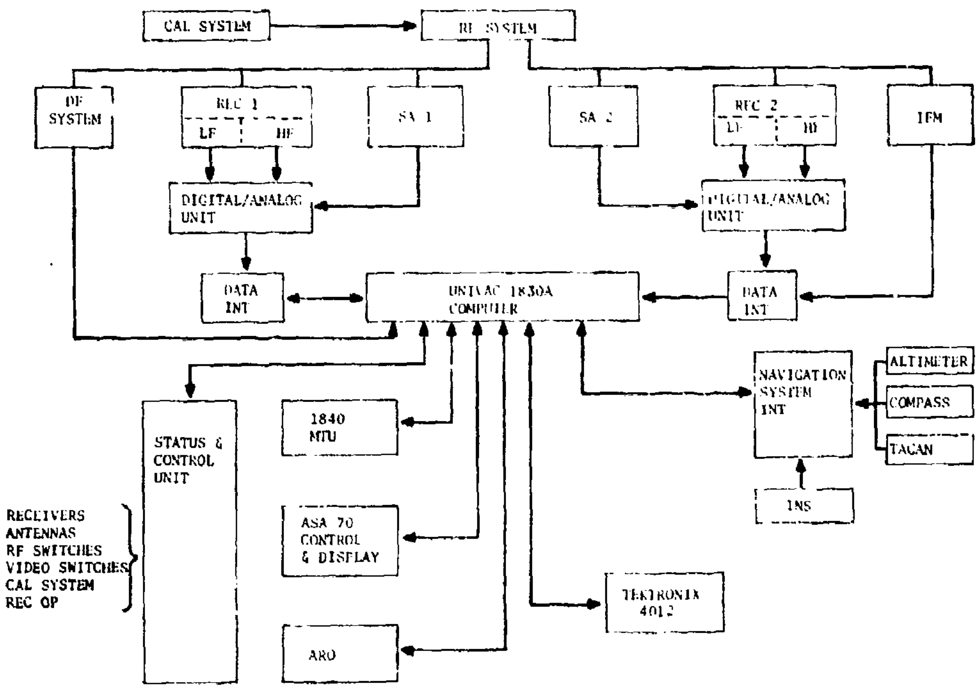


Figure 1. EMPASS Block Diagram

This report describes the software developed for the airborne data acquisition function, including the design goals for the recording of raw data on a pulse-to-pulse basis; the on-line displays provided for operator control, system monitoring, and data analysis; and the provisions for data simulation. A section on software structure describes how these design goals are implemented in the initial system. Graphical radiation patterns and a sample statistical summary of pulse information are presented as examples of test results.

DESIGN GOALS

The program, EASY 100, was designed for general puspose data acquisition (Figure 2). The design criteria were to store digital RF signal pulse parameters on magnetic tape compactly, to provide real-time analysis for operator use, and to be as reliable or fail-safe as possible in this data acquisition mission.

DATA RECORDED

To allow versatility in EMPASS test capability, digital RF signal data is recorded on a pulse-to-pulse basis, providing actual pulse streams for later analysis (Figure 3). The slow magnetic tape units impose a maximum data rate of 1 KHz on the system, but special provisions are made for cases where all pulses cannot be recorded during a sample interval. The operator selects the sample interval, and may choose a fixed sample size of 256 pulses or allow the sample size to be a function of the data rate and sample interval. In the latter case, data exceeding the maximum rate is recorded by segmenting the sample interval and recording pulses in bursts, so that short pulse streams are obtained throughout the selected interval and gaps are reduced (Figure 4).

Aircraft navigation parameters and system status information are recorded with each sample of signal data (Figures 5 and 6). Rather than recording the different data types as separate short records or buffering larger amounts of each data type, all inputs are allowed to flow directly into the large output buffer. This automatically achieves a chronological ordering, reduces processor time required for data handling, and achieves efficiency in tape start/stop operations. Further, in the event of tape error causing only a portion of the tape to be recovered, the data accessible will be meaningful.

Space in a 4096-word output buffer is allocated dynamically as an input area. The space is identified by data type, sample size, and current time, and it is linked to space allocated previously for the same data type (Figure 7). The input operation is then initiated and the processor freed, possibly to handle other requests for space. When there is not enough

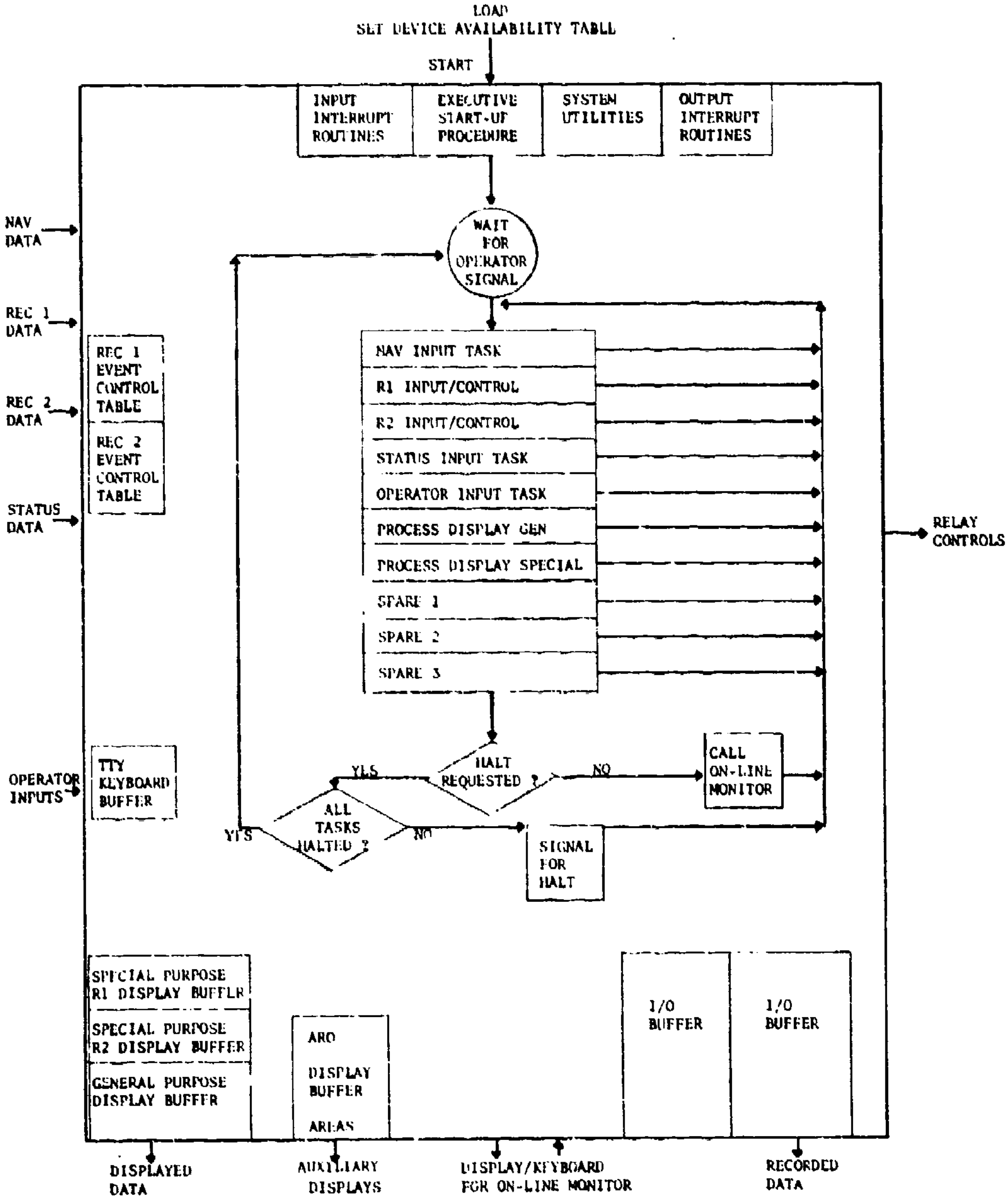
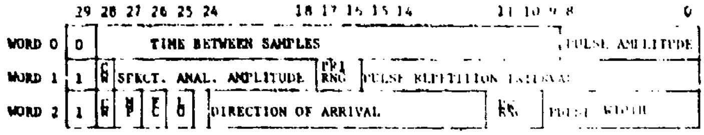


Figure 2. EASY 100 Flow Diagram

RECEIVER DATA FORMAT



WORD	BITS	CONTENTS	RESOLUTION	RANGE
0	0-8	Amplitude	5/511 Volt	0-5 Volts
	9-28	Time Between Samples	1 μsec	0-1048575 μsec
	29	= 0		
1	0-15	PRI Mantissa		[illegible]
	16-17	PRI Characteristic		0-3
		= 00, Multip . (0-15) by	.01 μsec	25-655.35 μsec
		= 01, Multipiy (0-15) by	.16 μsec	655.36-10485.6 μsec
		= 10, Multiply (0-15) by	1.28 μsec	10485.76-83886.8 μsec
		= 11, Multiply (0-15) by	10.24 μsec	83886.08-671078.4 μsec
	18-27	Spectrum Analyzer Amplitude	5/511 Volt	0-5 Volts
	28	= 1, CW for S.A.		
	29	= 1		
2	0-9	Pulse Width Mantissa		0-1023
	10-11	Pulse Width Characteristic		0-2
		= 00, Multiply (0-5) by	.01 μsec	[illegible]-10.23 μsec
		= 01, Multiply (0-5) by	.16 μsec	10.24-163.68 μsec
		= 10, Multiply (0-5) by	.64 μsec	163.84-654.72 μsec
	12-23	Direction of Arrival or MSB = 180°		[illegible]
	12-24	IFM Frequency 0-23	1MHZ	2000-8000 MHZ
	25	= 1, WJ-1140 Lock on		
	26	= 1, IFM Frequency Change		
	27	= 1, IFM Pulse Coincidence		
	28	= 1, CW Flag		
	29	= 1		

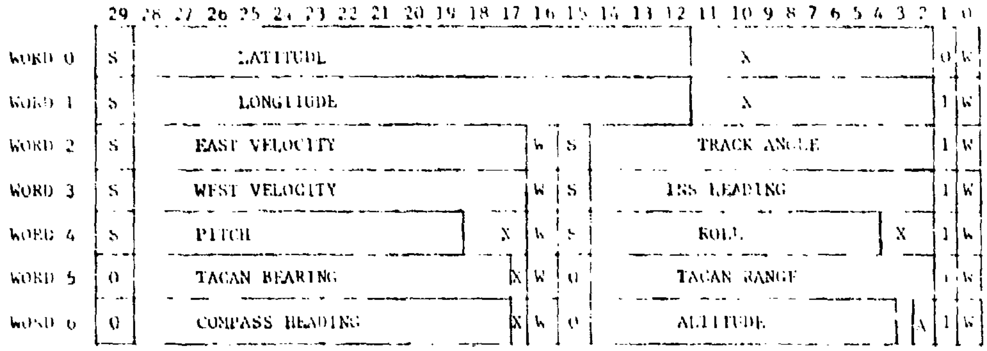
Figure 3. Pulse Parameters

FOR SAMPLE INTERVAL = 1/4 SEC

Input Rate (KHZ)	1	2	3	4	5	10	20
% Data Recorded	100	50	33	25	20	10	5
Time Data Recorded (MS)	256	128	84.8	64	51.2	25.6	12.8
Time Data Lost (MS)	0	128	171.2	192	204.8	230.4	243.2
Max. Gap (MS)	0	16	21.4	24	25.6	28.8	30.4

Figure 4. Data Rates

NAVIGATION DATA FORMAT



WORD	BITS	CONTENTS	LSB (BIT)	MSB (BIT)	RANGE
0	12-29	Latitude (BAMS)	.00137° (12)	90° (28)	0 to ± 180°
1	12-29	Longitude (BAMS)	.00137° (12)	90° (28)	0 to ± 180°
2	2-14	Track Angle	.01° (2)	90° (13)	0 to ± 180°
3	2-14	Ins Heading	.04° (2)	90° (13)	0 to ± 180°
2	16-29	East Velocity	.1 KT (16)	409.6 (28)	0 to ± 819.2 KT
3	16-29	West Velocity	.1 KT (16)	409.6 (28)	0 to ± 819.2 KT
4	4-14	Roll	.18° (4)	90° (13)	0 to ± 180°
4	19-29	Pitch	.18° (19)	90° (28)	0 to ± 180°
5	2-13	Tacan Range	.1 NM (2)	204.8 NM(13)	0 to 409.6 NM
5	17-28	Tacan Bearing	.09° (17)	180° (28)	0 to 360°
6	3-13	Altitude	20 Ft (3)	20480 Ft (13)	0 to 40960 Ft
6	17-28	Compass Heading	.09° (17)	180° (28)	0 to 360°

S Indicates sign bit for following binary field (0 = POS)
W Indicates warning bit for preceding binary field (0 = BAD)
X Indicates field not used
0 Indicates field is always 0
1 Indicates field is always 1
A Indicates altimeter type (0 = barometric, 1 = radar)

Figure 5. Navigation Parameters

CALIBRATION SYSTEM

29	25				0
0 0 0 0	Calibration Frequency (7 high-order digits)				
0 0 0 1	Calibration Frequency 3 low-order digits 14	13 Selection Indicators 7			
0 0 1 0	Calibration Attenuation 17	16 S	15 Calibration Power Meter 4		
0 0 1 1	R N G	22 Calibration Pulse Width 15	R N G	11 Calibration PRI	

ANTENNA CONTROL SYSTEM

29 26	25 16	15 8	7 0
0 1 0 0		Tail Angle	Wing Angle

RECEIVER POSITION 2

29 26	25 11	10 4	3 0
0 1 0 1	Selection Indicators	Equalizer Attenuation	Line Attenua.
0 1 1 0	Selection Indicators		
0 1 1 1		21 Selection Indicators	

RECEIVER POSITION 1

29 26	25 11	10 4	3 0
1 0 0 0	Selection Indicators	Equalizer Attenuation	Line Attenua-tion
1 0 0 1		21 Selection Indicators	

Figure 6. Status Data

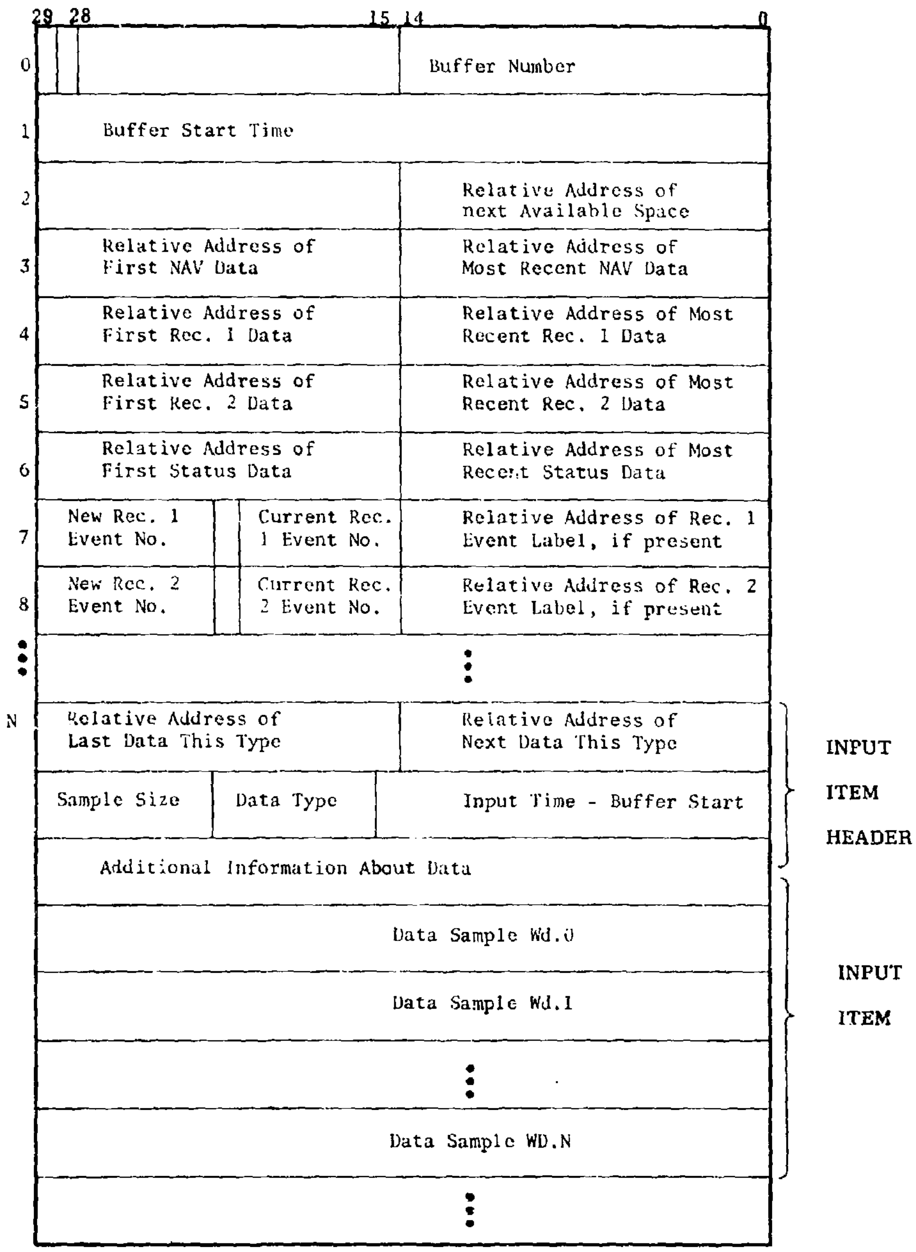


Figure 7. Data Buffer

buffer space remaining to honor a request, the output operation is initiated and the alternate buffer used for allocating input space. In this way it is possible to have as many as four input operations and an output operation occurring simultaneously while the computer is free to perform the on-line processing needed for the operator.

DATA DISPLAYED

The Easy 100 system displays information to the operator through two media--the ASA 70 16-in.-diameter multipurpose display and the ARO, an auxiliary readout unit containing a 20 X 20 character display. The general display on the ASA 70, used for total system monitoring, is updated every second. The date, time, and lapsed time are presented along with all the information from the interface to the LTN-51 inertial navigation system. Items showing the status of receivers, antennas, and relay systems are given and flashed if there is a disagreement with the operator selection. Up to 40 characters from the operator's keyboard may also be displayed to allow comments to be formatted before recording, and program detected error conditions are made apparent. In addition to this system monitoring information, the general display contains a rectangular plot for each receiver position. Up to 180 points of signal amplitude data are displayed for each receiver, in volts (0-5) or computer calibrated in 10-dBm steps. The abscissa is normally in seconds and is updated every other second. After the display is filled, it may wrap around or shift points as the operator chooses.

The operator may change the two receiver plots independently to select power versus azimuth angle, distance, elevation angle or frequency. These plots are always updated, even if not displayed. When a new event is started for a receiver, the plot area for that receiver is cleared, but when an event is ended the data remains on display until another event begins using that receiver. The operator has many options for data displayed. Amplitude displayed may be either the average, the maximum, or the first in a data sample. Azimuth angle (direction from the emitter to receiver) may be calculated from either a TACAN bearing or track angle of the aircraft. Amplitude at a certain angle may be either the last one received at that angle or the maximum value received at that angle. The latter option is useful in finding main beams, peak power, or excluding noise.

In addition to the general display with the optional receiver data plots, the operator may choose a special display containing a large polar plot of either receiver data. This may be used to display a radiation pattern as the aircraft flies around a fixed source.

The ARO displays the date, time, navigation, and receiver parameters normally seen on the ASA 70 monitor display, but the operator may select an event history, an error history, frequency control data files, or an on-line monitor capability used in conjunction with the ASA 70 keyboard. These displays provide the operator with additional system information and a means of monitoring the system in the event of ASA 70 display failure.

DATA SIMULATION

The EASY 100 system was designed and developed to include a data simulation for each of its inputs. This allowed for program development before some hardware became available, it allows for tests to be "pre-flown" without the expense of operating the aircraft, and it provides some backup operation in the event that a device develops problems during a test.

At program initiation, the operator establishes a system configuration or a device availability table (Figure 8) which indicates the manner in which each input and each output is to be handled. System inputs include navigation data, receiver position 1 data, receiver position 2 data, system status data, and operator inputs. Each data input may be from the proper interface unit, from an 1840 magnetic tape unit, from a 1540 magnetic tape unit, or from core memory, while operator inputs may be from ASA 70 control panel, from an SST keyboard, from a standard teletype keyboard, or from a core memory table of "canned" start-up information.

29 27	26 ON-LINE MONITOR 24	23 DISPLAY OUTPUT 21	20 CONTROL OUTPUT 18	17 TAPE OUTPUT 15
	0 = NO MONITOR 1 = TEKTRONIX 2 = TTY 1532	0 = ASA 70 INTF 1, 2, 3 = BYPASS OUTPUT	0 = CS INTF 1, 2, 3 = BYPASS OUTPUT	0 = 1840 MT 1 = BYPASS OUTPUT 2 = 1540 MT 3 = BYPASS OUTPUT
14 OPERATOR INPUT 12	11 STATUS INPUT 9	8 REC2 INPUT 6	5 REC1 INPUT 3	2 NAV INPUT 0
0 = ASA 70 INTF 1 = SST 2 = TTY 1532 3 = FAKE INPUT	0 = CS INTF 1, 2, 3 = FAKE INPUT	0 = REC DATA INTF 1 = 1840 MTU2 2 = 1540 MTU4 3 = FAKE INPUT	0 = REC DATA INTF 1 = 1840 MTU2 2 = 1540 MTU4 3 = FAKE INPUT	0 = INS INTF 1 = 1840 MTU1 2 = 1540 MTU3 3 = FAKE INPUT

Figure 8. Device Availability Table

System outputs include raw data storage, control information, a general purpose operator display, an auxiliary operator display, and an on-line monitor for system evaluation and testing. The data storage may be to an

1840 magnetic tape unit, to a 1540 magnetic tape unit, or it may be bypassed. Other outputs are to the proper interface units or bypassed. The on-line monitor uses a teletype or a TEKTRONIX display/keyboard unit for its operation.

Off-line programs are available to produce the tapes of simulated data when given flight plans and data specifications. Programs are being developed to retrieve data from completed tests for later use in the simulation mode.

SOFTWARE STRUCTURE

The EMPASS acquisition system known as EASY 100 is essentially a time-sharing system of priority-ordered tasks with a controlling executive routine. These tasks may be classified as data input tasks, control tasks, or processing tasks. The input and control tasks initiate data input or issue control output messages and relinquish control, after setting the time they wish to be called again. Program interrupt occurs at the completion of the I/O operation and automatically accesses an interrupt routine unique to the I/O channel to perform necessary bookkeeping functions before returning control to the point of interrupt. Other processing tasks operate in a segmented fashion so control may be shared among the 10 tasks in the system design. Seven of these tasks are implemented in the initial system.

Input of aircraft navigation data is considered to be the highest priority task since other data is position relative. Control and input from the two receiver positions and system status input tasks follow in that order, while the tasks of communicating with a human operator are performed on a lower priority basis. Separated into an operator input task and two display update tasks, these procedures allow operator controls over the data acquisition hardware and software while providing on-line processing for immediate data display.

Common to all tasks are two large I/O buffers used for data input and output and the procedures which initialize these buffers, allocate buffer space dynamically to requesting input tasks, link data samples of the same type within a buffer, and write a full buffer to magnetic tape while the alternate buffer is used for input.

EXECUTIVE

The executive routine (Figure 9) performs the required initialization and start-up functions. During the start-up phase, it permits the operator to establish:

1. System configuration (a device availability table which gives the system some flexibility in the event of peripheral failure).

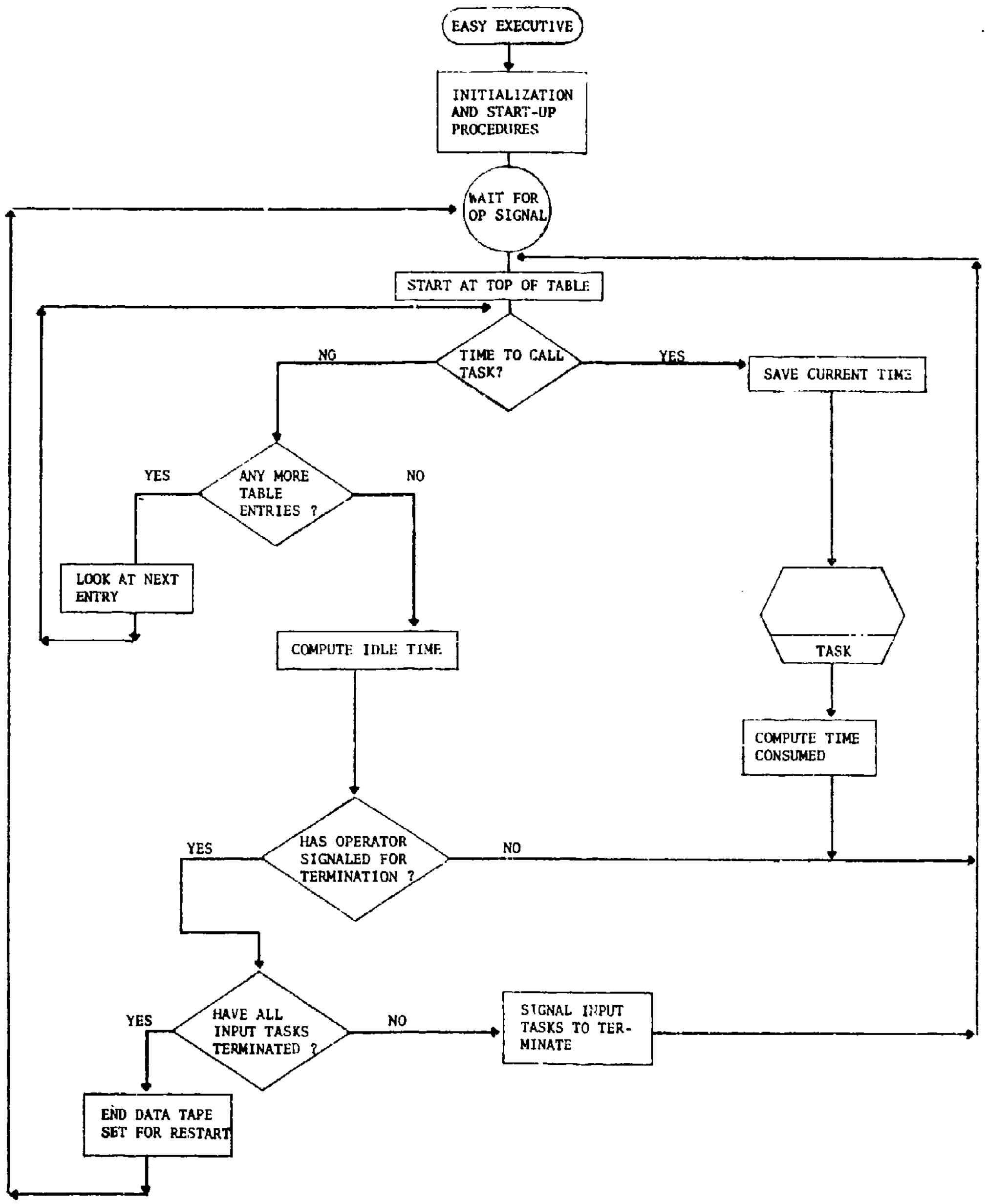


Figure 9. Executive Routine

2. Current date and time, which allows all data to be uniquely labeled.

3. A starting event number, which allows each test or measurement to be uniquely labeled.

4. Which tape unit is ready to be used for recording data.

When start-up is completed, the executive polls a priority-ordered table of task call times, comparing each call time with the computer's real-time clock. When the clock exceeds the call time, the task is initiated. Each task resets its call time before returning so that it may be called again on the next poll, after some fixed time delay, or, if call time is set to a maximum value, it will not be called again. The executive computes and stores the amount of time that each task consumes as well as its own "idle" time; i.e., the amount of time between the last task execution and the next call time in the table. An on-line monitoring procedure can be used to make these and other system values available to the operator.

When an operator request to halt the system has been processed by the operator input task, the executive communicates the need for an orderly termination to each task in the system. When all tasks have set their call times to maximum value, indicating termination, the executive executes the instructions that will stop the system in a state ready for restart at the operator's signal.

NAVIGATION DATA INPUT

The navigation data input task (Figure 10) is the highest priority task in the time-sharing system, but it is also the shortest task, both in running time and in coding required. It consists of an input-initiate procedure, NAVIN, and an input-complete interrupt procedure, ENSINT. If simulated navigation data is being used, the magnetic tape interrupt procedure ESMTIP performs the input-complete functions, and if no navigation data input is available, there is no interrupt function.

The input-initiate procedure is called by the executive when the computer's real-time clock exceeds the entry for the navigation task in the table of task call times. It obtains space in the I/O buffer linked into the navigation data links, and consults the device availability table to determine how navigation data input is being handled.

If the unit which interfaces the inertial navigation system is available, the procedure simply initiates an input from that device, resets its call time according to the current operator-established navigation interval, and returns control to the executive.

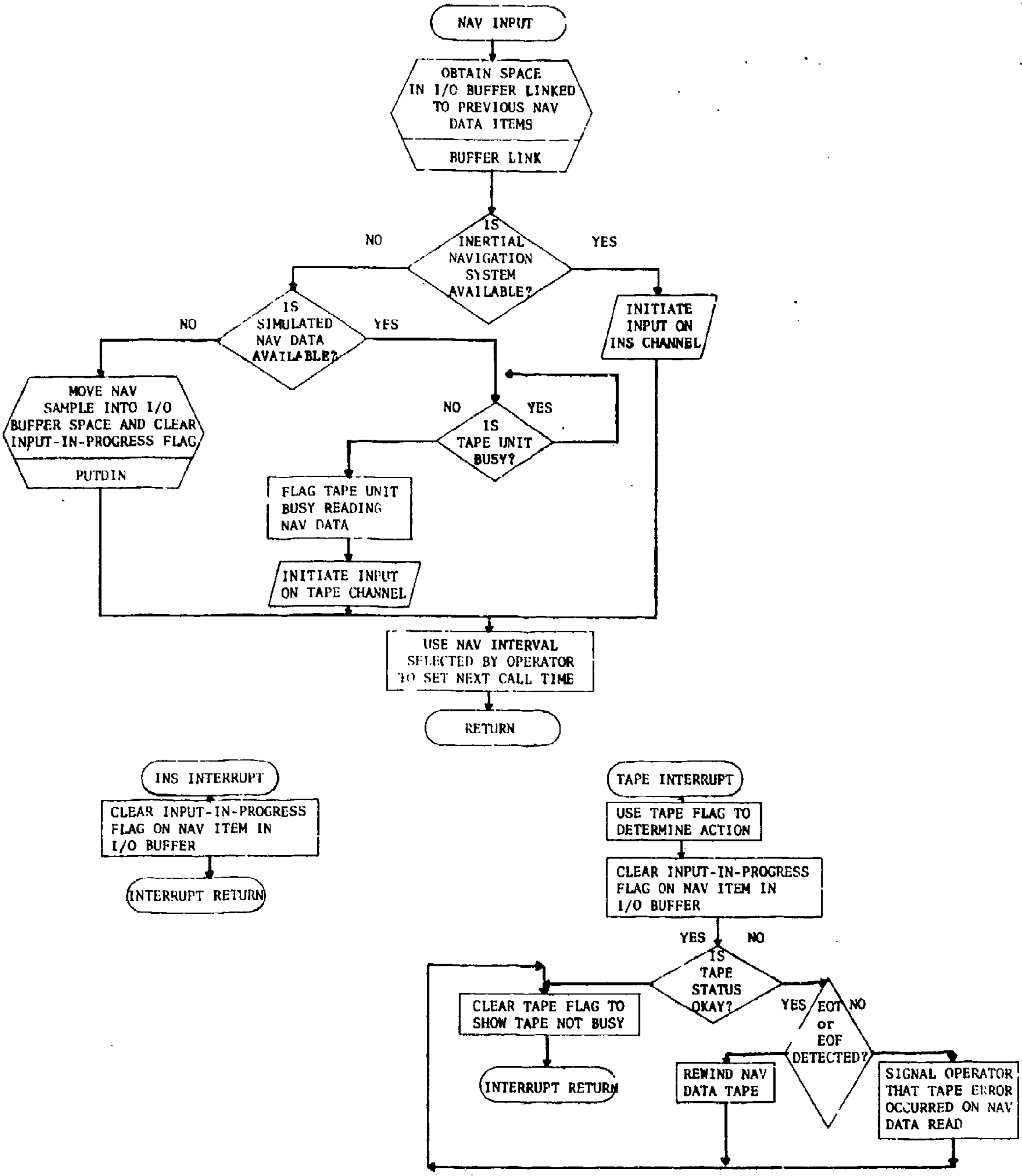


Figure 10. Navigation Data Input Task

If simulated navigation data is being obtained from a magnetic tape unit, the procedure waits for a flag to indicate that the tape is not busy, sets the flag to signal that the tape unit is busy reading navigation data, and then addresses the proper tape unit with a read command before resetting call time and returning.

If navigation data is not available at all, the procedure calls a routine to move a prestored sample of navigation data into the buffer space and clear the input-in-progress flag. It then resets the call time and returns control as above.

When a data sample has been completely read in, the input-in-progress flag on the item header in the I/O buffer must be cleared. This function is performed by the interrupt procedure accessed when the input is completed. If the input is from the navigation interface unit, the interrupt procedure ENSINT is accessed to perform this function. If the input is from a magnetic tape unit, the interrupt procedure ESMTIP is accessed. This procedure uses the system tape flag to determine what type of tape action has occurred and what interrupt processing is needed. When it finds the flag set to indicate a navigation data read, it clears the input-in-progress flag on the navigation item. This procedure also checks the status from the proper tape unit, signals the operator if a bad read has occurred, and rewinds the navigation data tape when an end of file is encountered. When all registers have been restored, it clears the system tape flag to indicate that the tape unit is no longer busy, and returns control to the point of interrupt.

RECEIVER POSITION 1 (INPUT AND CONTROL)

The second highest priority task in the EASY 100 system involves receiver position 1 . When the computer's real-time clock exceeds this call table entry, the procedure REC1IN is called to determine what processing is needed at this position. For each receiver position, procedures are available to allow input of signal data, control of the calibration system, control of the spectrum analyzer, control of the receiver frequency, or control of the antenna position.*

When the operator enters a request to start an event involving receiver position 1, he may select any one of the controls available. This control request is passed to the receiver task through the event control table EVCON (Figure 11). For each of 100 possible receiver 1 events, this table stores event start time, controls selected, length of time the event was in progress, and the number of signal data samples recorded, thus providing a history of operation of the receiver position during a program run.

* The last three control procedures are not implemented in the initial system.

RECEIVER POSITION ONE ENTRIES	21 EVENT START TIME IN SECONDS 10		9 CONTROLS SELECTED FOR THIS EVENT 0
	29 EVENT DURATION TIME 17	16 NUMBER OF DATA SAMPLES RECORDED IN THIS EVENT 0	

100 ENTRIES

RECEIVER POSITION TWO ENTRIES	29 EVENT START TIME IN SECONDS 10		9 CONTROLS SELECTED FOR THIS EVENT 0
	29 EVENT DURATION TIME 17	16 NUMBER OF DATA SAMPLES RECORDED IN THIS EVENT 0	

100 ENTRIES

Figure 11. Table EVCON

Another table, ERECV (Figure 12), contains information about the event in progress and is used for communication between the various procedures operating within the task. On each initial call to this task (i.e., in response to operator's input of start event), this table is set to contain only the current event number and a procedure selection switch of zero, which causes REC1IN to initiate a call on the procedure RDATA.

ITEM 0	Wd. 0	29 RECEIVER ONE PROCEDURE SELECTION SWITCH 15		14 CURRENT RECEIVER ONE EVENT NUMBER 0
	Wd. 1	29 DATA INTERFACE 1 SELECT CODE 24	17 R1 HI DATA RATE FLAG 15	14 RECEIVER ONE--CURRENT SAMPLE SIZE 0
	Wd. 2		17 PRI VALUE FROM LAST REC1 DATA SAMPLE 0	
	Wd. 3	29 CONTROL INFORMATION FOR RECEIVER POSITION ONE 0		
ITEM 1	Wd. 0	29 RECEIVER TWO PROCEDURE SELECTION SWITCH 15		14 CURRENT RECEIVER TWO EVENT NUMBER 0
	Wd. 1	29 DATA INTERFACE 2 SELECT CODE 24	17 R2 HI DATA RATE FLAG 15	14 RECEIVER TWO--CURRENT SAMPLE SIZE 0
	Wd. 2		17 PRI VALUE FROM LAST REC 2 DATA SAMPLE 0	
	Wd. 3	29 CONTROL INFORMATION FOR RECEIVER POSITION TWO 0		

Figure 12. Table ERECV

Receiver Data Input

The procedure RDATA is common to both receiver tasks. It is responsible for entering data in the I/O buffer, linked into the proper receiver data links. It determines which receiver position task has called it, obtains the event number from the table ERECV, and accesses the proper entry in the table EVCON. Sensing the beginning of an event, it sets start time in the EVCON entry and causes an event start label to be linked into the I/O buffer, storing all information available on the status of the system at the time the event begins. It then tests the selected controls stored in the EVCON entry to see what procedure should be called on the next call to this task.

If no controls are requested on a receiver event, the procedure selection switch in the table ERECV will remain zero, and each call on this task will result in a call on RDATA (Figure 13). This procedure will initiate input of receiver data according to the device availability table and monitor the number of data samples linked into the I/O buffers. Control is relinquished as soon as the input has been initiated and the next call time established.

If data is input from the receiver data interface unit, the interrupt procedure EDATA1INT is accessed when the input is complete. Under normal data input operation, this procedure simply clears the input-in-progress flag on the data item and issues a return to the point of interrupt.

If data is input from a magnetic tape unit, this function is performed by the procedure ESMTIP which determines from the system tape flag that simulated receiver position 1 data has been read in from tape. This procedure also signals the operator if a bad read status is detected, and rewinds the tape if an end of file is detected.

If data is simply moved from a prestored sample in core memory, no interrupt routine is accessed.

The procedure RDATA also attempts to determine the proper size for a receiver data sample. On each call after the initial data input, if no controls are in effect, it calls a routine to examine the last data sample stored and estimate the number of pulses expected in the current operator-established sampling interval. If the last data sample obtained indicates that the data rate is too high to record all pulses emitted in a sample interval, then a high data rate flag is set in the table ERECV and special processing is begun.

When the RF signal data being recorded exceeds the maximum of 256 pulses per sample interval, the interval is segmented to avoid collection of all pulses at the beginning of the interval. Sensing the high data rate flag set, the procedure which initiates the data input requests buffer space for the full sample, but initiates input of only one-eighth of the pulses desired. It then sets the computer countdown clock to cause a program interrupt when one-eighth of the sample interval has elapsed.

The input complete interrupt occurs when the 32 pulses have been read in, but the interrupt routine EDATA1INT does not clear the input-in-progress flag until the eighth group is complete.

The countdown clock interrupt routine, ECDTIMER, is accessed when one-eighth of the sample interval has elapsed. It initiates the input request for the next group of pulses and sets the countdown clock for the next interrupt. When the last segment of the sample interval has expired, the clock interrupt routine disables the clock processing, terminating the sample input.

If the data rate remains high, the next call on the receiver data input task will begin another segmented sample and again start the countdown clock processing. The time-between-samples value on the data being recorded makes it possible to reconstruct the actual time of arrival of each pulse, identifying and measuring the data gaps within the sample interval.

Calibration Control

When control of calibration is selected by the operator, the procedure selection switch will be set to 1 after the event start label has been linked into the I/O buffer. This means the second call on the task will cause REC1IN to call the procedure RCAL (Figure 13) to calibrate the receiver selected. This procedure, common to both receiver tasks, will read in status information to obtain a power meter reading and the amount of attenuation which the receiver operator has set for the maximum power level. It then issues control messages to the calibration attenuator increasing attenuation in 5-dB steps. After each control message, it sets the procedure selection switch to zero, resets its call time to wait a full second before the next call on this task, and returns. When the task is called again, control passes to RDATA to obtain a sample of signal data at the prescribed attenuation. Absolute power, passed through the table ERECV, is stored in the I/O buffer with the signal data.

Calls on the receiver task, then, initiate alternate calls on the RCAL and RDATA procedures. RCAL examines each sample of receiver data to determine the average amplitude in volts at each power level. It passes this information to procedures which update the operator's display and also

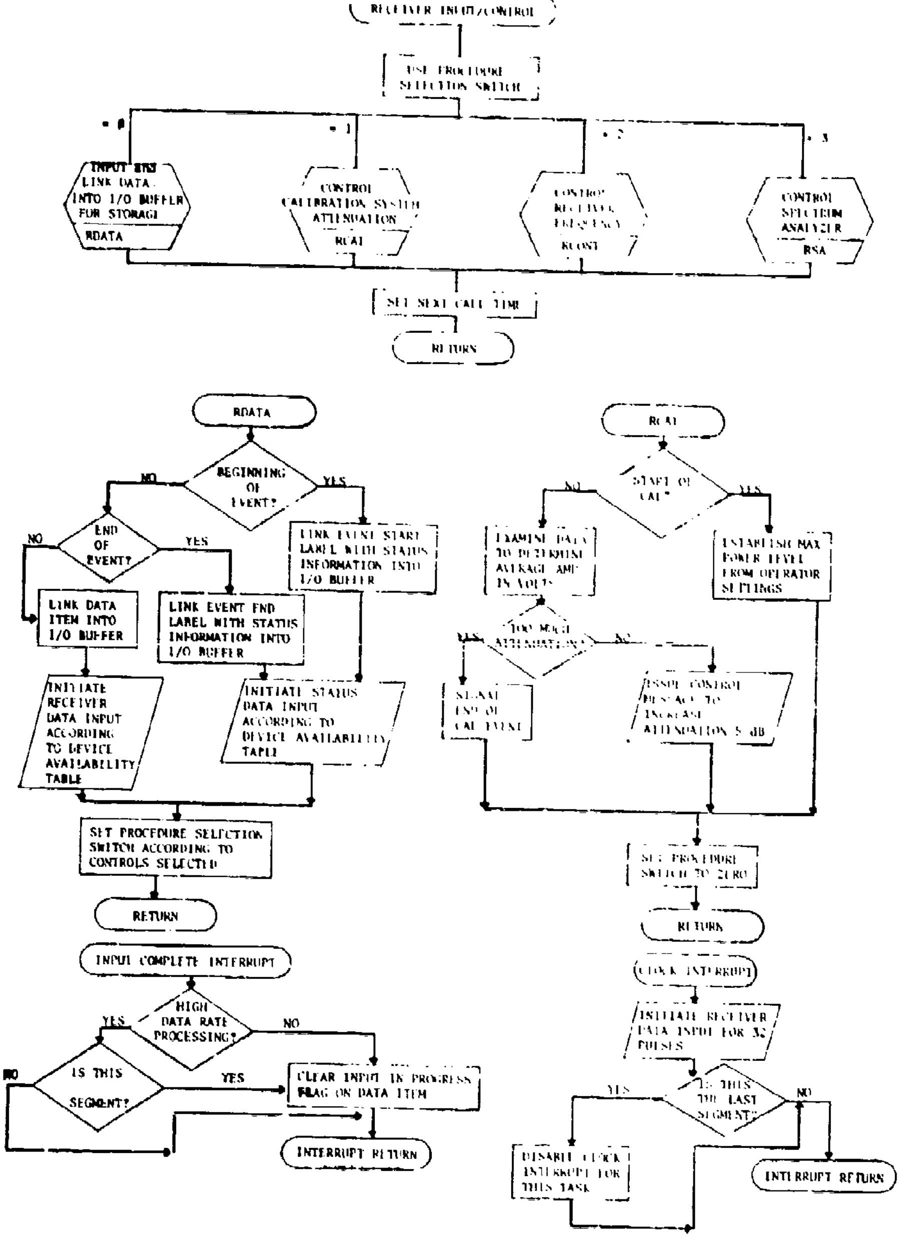


Figure 13. Receiver Input/Control

uses it to determine when the attenuation is too great to receive a measurable signal. At this point or when the attenuation exceeds an upper limit of 129 dB, the calibration is considered complete. The next call on the task causes the RDATA procedure to store an event end label in the I/O buffer and set the maximum call time so the task will be terminated.

RECEIVER POSITION 2 (INPUT AND CONTROL)

The third highest priority task in the EASY 100 system involves receiver position 2. When the computer's real-time clock exceeds this call table entry, the procedure REC2IN is called to determine what processing is needed at this position. The procedures available for receiver position 1 are also available to receiver position 2. Since the tasks are executed serially and all storage items are separate for receiver 1 and receiver 2, the two positions may be operated completely independently. All information presented above for receiver position 1 also applies to receiver position 2.

Hardware is not yet available for operation of receiver position 2, but data simulation from this position and fake input operations have both been implemented, recording data in the receiver 2 links and producing on-line displays for operator analysis.

SYSTEM STATUS INPUT

The fourth task in the EASY 100 system is the input of system status information. This data maintains a record of all changes in system controls, provides a vehicle for entering operator comments at any time, and allows an on-line error detection capability.

The procedure SYSTEMSTAT is called by executive at intervals established by the operator. This procedure obtains space in the I/O buffer linked into status data links and consults the device availability table to determine how this input is being handled. If the control and status interface unit is available, a utility procedure, STATUSIN, is called to initiate input of status data from the entire system. If the interface unit is not available, a sample of status information is moved from core into the buffer space.

A system flag set by the operator input task indicates when a keyboard buffer contains an operator comment to be stored in the I/O buffer along with system status data.

On-line error detection is provided by examining the system status data and comparing it with the relay commands which have been issued. Any discrepancies are called to the operator's attention by flashing items on the status display provided.

OPERATOR INPUT

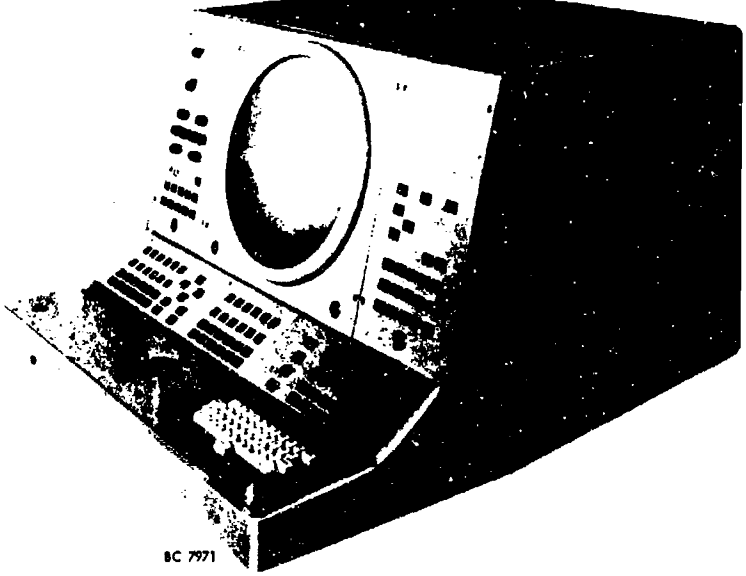
Operator input can come from one of three sources--an ASA 70, an SST or a teletype. The latter two merely simulate inputs in ASA 70 format. During initialization, one selects the input medium. The chosen device is interrogated constantly via a pending input with monitor. When an input occurs, an interrupt routine, KINT, saves the input code and partially decodes it. If this happens during initialization, the input is part of either the date, time, event number or tape number. These values are accumulated and formatted for the displays. Otherwise, the partially decoded input is stored to be processed and executed at a later time by KIM, which calls the necessary processing routine and checks for illegal codes. A new input is requested immediately, even when the old one is still waiting to be processed. If the SST is chosen, the inputs are used in combination to form all possible ASA 70 inputs.

The ASA 70 (Figure 14) has been used as the primary input-output medium for the computer operator. The ASA 70 consists of an 1830A computer interface, a control tray, at least 100 labeled switches (48 of which are active), a 16-in.-diameter multipurpose display, and a ball-type cursor. The interface includes a test option for manually setting and sending up to three words to the control tray.

Possible inputs from the ASA 70 are switches, keyboard characters, and cursor changes. The program is controlled by the pressing of the switches. "Matrix Select" switches choose a set of 12 interdependent options on the "Multifunction" switches (Figure 15). "Monofunction" switches select a special independent function (Figure 16). The matrix and monofunction switches have green and amber background illumination. They have been programmed to light amber if and only if the associated function is selected. A unique set of 12 legends automatically appears on the multifunction switches with the depression of each matrix select switch, except for the last one, which clears all switches. Through the use of the 12 matrix select and 12 multifunction switches, there is a choice of 132 functions. There are 24 monofunctions, not all of which light. The labels and functions of those implemented are given below. In order to light the monofunction switch lamps, one sends the current status of either the upper 12 or lower 12 to the control tray. Therefore, any combination can be lit at any one time. However, only 12 actually have amber lights.

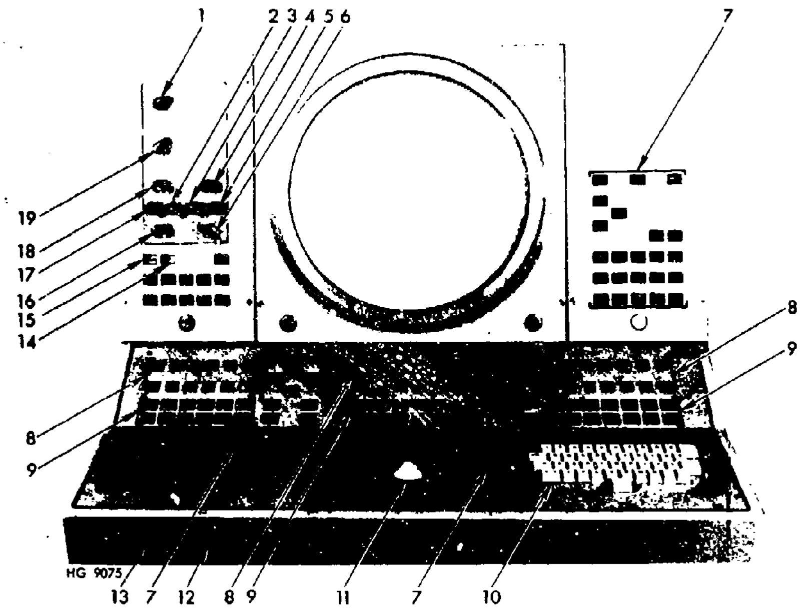
The tracking control ball assembly places the cursor (hook) symbol at any location on the CRT. The trackball sends over a pair of changes in x and y positions every 50 ms, whether or not there has been any change. Moreover, the input consists of the absolute value of the change, plus a sign bit. The program saves the trackball Δy in a special word if it senses a Δx.

The keyboard assembly is similar to a typewriter and consists of 44 alphabetical, numerical, and special character keys. These keys are



INDEX NO.	NAME	REF DESIG	FUNCTION
1	OFF LINE/ANALOG switch	A1S2	Permits the display of four channels, CHAN 1 thru CHAN 4, and CHAN 1 & 4 of video in the absence of certain digital input signals, when used in conjunction with the mode selector switch.
	CHAN 1		Provides scan converted radar
	CHAN 2		Provides low light level television (LLLTV)
	CHAN 3		Spare scan converter
	CHAN 4		Provides function generator (ellipses)
	CHAN 1 & 4		Permits superimposed display of channels 1 & 4
2	CHAN 2 BRIGHTNESS control	A1R3	Adjusts brightness of displayed video, channel 2
3	CHAN 3 BRIGHTNESS control	A1R13	Adjusts brightness of displayed video, channel 3
4	VERT CENTERING	AR1R54	Adjusts relative vertical positioning of display on tube face
5	CHAN 4 BRIGHTNESS control	A1R6	Adjusts brightness of displayed video, channel 4
6	VECTOR BRIGHTNESS control	A1R22	Adjusts brightness of displayed vectors
7	Monofunction switch indicators		Enables operator to communicate with computer. Both single and double lamp switches are used. Single lamp switches are always lighted green and cannot be lighted by the computer. The double lamp switches are green and amber. Green is the normal background and amber is the computer lighted response.
8	Matrix switch indicators		These 36 two-position switches may be illuminated green or amber and have several legends that may be projected on their surface. The digital data computer sends information to the operator via these legends, and the operator uses the switch function to send information to the computer.
9	Matrix select switch indicators		Presents information to computer when pressed by operator. Indicators are double lamp pushbutton switches, one switch for each PRO in the three matrices, A, B, and C. The green lamp is on at all times while the amber lamp comes on only when computer responds by lighting the corresponding PRO in adjacent matrix.

Figure 14. ASA 70



INDEX NO.	NAME	REF DESIG	FUNCTION
10	Keyboard		Allows operator to communicate with computer, keys are A to Z, 0 to 9, REPEAT, SPACE, EOM, Minus, Plus, NEXT LINE, Period, BACK, and CANCEL.
11	Tracking ball control		Provides signals which correspond to position of manually positioned ball, this information is used by DPS and computer to select cursor (hook) symbol and display it in location corresponding to position of tracking ball.
12	Time totalizing meter	M1	Indicates elapsed hours of operation
13	Lamp intensity controls (2)		Enables operator to adjust brightness of indicator switches and controls. One control adjusts matrix A, B, and C PRO switch-indicator brightness; the other adjusts matrix selection switch-indicator, monofunction switch-indicator, and keyboard and maintenance panel brightness. Both controls are located under left side of control tray.
14	TEST indicator	A1DS3	Indicates MODE SELECTOR switch is not ON LINE position
15	OVERFLOW indicator	A1DS4	Indicates excessive information for display tube
16	CHARACTER BRIGHTNESS control	A1R18	Adjusts brightness of displayed characters
17	CHAN 1 BRIGHTNESS	A1R11	Adjusts brightness of displayed video, channel 1
18	HORIZ CENTERING control	AR3R54	Adjusts relative horizontal positioning of display on tube face
19	MODE SELECTOR switch	A1S1	Permits display of video in absence of certain digital input signals when used in conjunction with OFF LINE/ANALOG switch. Also controls illumination of TEST indicator.
	ON LINE		Permits normal on line operation
	ANALOG TEST		Display analog test pattern
	MATRIX TEST		Display matrix test pattern
	REGISTRATION TEST		Displays registration test pattern
	VECTOR TEST		Displays vector test pattern
	TYPE TEST		Displays type test pattern
	FUNCTION GEN TEST		Displays function generator test pattern
	OFF LINE/ANALOG		Displays television test pattern

Figure 14. ASA 70 (Continued)

MATRIX SELECT

1	2	3	4	5	6	7	8	9	10	11	12
REC 1	REC 2	EMCON 1	EMCON 2	DISPLAY 1	DISPLAY 2	ARO FUNCTION	NAV INTERVAL	EMCON DATA			MASTER CLEAR

MULTIFUNCTION

1	CAL	CAL	FILE 1	FILE 1	TIME	TIME	MONITOR	50	ENTER			
2	S/A	S/A	FILE 2	FILE 2	AZIM	AZIM	EMCON	100	LINE 1			
3	DF	DF	FILE 3	FILE 3	RANGE	RANGE	EVCON	200	LINE 2			
4	ANT	ANT	FILE 4	FILE 4	ELEV	ELEV	ERROR	400	LINE 3			
5	POL	IFM	DF	DF	FREQ	FREQ	EVCON 1	800	LINE 4			
6	START	START	START	START	POLAR	POLAR	EVCON 2	1600	LINE 5			
7	RADIAL	RADIAL	FILE 5	FILE 5				64	SAVE			
8	ORBITAL	ORBITAL	FILE 6	FILE 6				128	FILE 1			
9	NOSE	NOSE	FILE 7	FILE 7				256	FILE 2			
10	TAIL	TAIL	FILE 8	FILE 8				512	FILE 3			
11	WING	WING	ANT	ANT				1024	FILE 4			
12	STOP	STOP	STOP	STOP				2048	CLEAR			

Figure 15. Matrix Select and Multifunction Switches

NO.	EASY NAME	CODES	LAMPS
1		16	
2		17	
3		20	
4		21	
5		22	x
6		23	x
7		24	x
10		25	x
11		15	x
12	HALT/RESTART	3	x
13	CLOCKWISE	7	
14	CROSSWISE	10	
15	TAPE 2 READY	2	
16	POINTWISE	6	
17	TAPE 1 READY	1	x
20	TAPE 2 READY	5	x
21	END TAPE	12	x
22	HALT/RESTART	26	x
23	CW DATA	13	
24	HOOK	14	
25	MAX	11	
26		27	x
27		30	x
30	END TAPE	4	
31	END TAPE	4	

Figure 16. Monofunction Switches

used to construct messages for display, and to initiate and control tactical situations. During the initialization procedure, EASY requests date, time, and event numbers for identifying the run. These are converted, formatted, and displayed on the MPD and ARO as they are received. During the test, keyboards are buffered and displayed in a line (of up to 40 characters) on the bottom of the MPD. Control characters have their normal meaning, except LINEFEED which will clear and start a new line with the next character. After a message has been composed, the EOM key must be pressed in order to transfer the message buffer. (The keys in this assembly are in series with the monofunction switches in the control tray.) During the input of data for EMCON files, all the formatting is done automatically; i.e., the operator does not have to type blanks and periods.

Pressing a switch results in a call on the procedure KSWPROC which determines the type of switch and illuminates the correct lamp. For a monofunction switch, a flag is merely set. For a matrix select switch, the matrix number is saved in order to interpret any multifunction switches, which actually call the processing routines.

Receiver data collection is controlled by two matrices, one for each receiver. After choosing either the receiver 1 or 2 matrix switch, all one must do in order to start recording receiver data is to press "START". This starts a new event which continues until "STOP" is pushed. If one desires other data to be recorded along with or in place of receiver data, one must push "CAL", "S/A", "DOA", "ANT", "IFM", or "POL" before "START". A display of time versus power is given unless a different option is selected by a "DISPLAY" matrix switch. These may be changed at any time during data acquisition.

GENERAL DISPLAY PROCESSING

The displays are updated every second through the task table by EUPDATE in four subtasks on a shared-timed basis. Date and time are always updated, i.e., every 1/4 sec. AUPDATE handles the information from the navigation interface which goes at the top of the ASA 70 and on the ARO. AUREC updates the normal time versus power rectilinear plots alternating between the two receivers. It looks in the buffer for the last receiver item, calculates the average (or maximum) amplitude and stores a point in the display buffer. UPSTAT displays the system status and checks for consistency. AUMISC updates miscellaneous information such as event number and error messages.

The time dependent display information is updated by AUREC which alternates between receivers on successive calls. First of all, it calls ALASTREC which searches for the last receiver item in the buffer, moves it, and averages the amplitudes. If no pulses are present, ALASTREC returns with the flag AINT set to inhibit plotting. This routine also averages crudely the frequency, PRI, and PW for digital display. It would be helpful to sort and display them graphically here, but this would imply a logarithmic plot or the operator setting a window.

The average amplitude is scaled down to display size (0-177 octal) and offset for the receiver. If the buffer is full and a moving display is desired, the set of points is shifted to the left. This has the effect of having the newest value always being added to the right. A mark appears to indicate the elapsed event time. Neither of these operations are straightforward since there is a discontinuity at zero.

SPECIAL DISPLAYS

Special displays are all handled through one task in the executive task table. They involve correlation of receiver and navigational parameters.

The most interesting display is an antenna pattern, which is a polar plot of average (or maximum) received power versus azimuth angle. Optional displays are rectangular plots of power versus azimuth angle, power versus range, power versus elevation angle, and power versus frequency.

Figures 17, 18, and 19 show some off-line hard-copy results for a typical data tape produced by EASY 100. On-line displays are similar. Figure 20 is a picture from the general display. A polar antenna pattern from the ASA 70 multipurpose display is illustrated in Figure 21.

```
DATE -  5/ 8/74*
RUN -          107
EVENT - 1010
START TIME - 11.28.52*
RECEIVER -           1
 BAND WIDTH - 1.00 MHZ
 IF ATTEN. - 12 DB
 RF ATTEN. - -0 DB
 TWT -         OUT
 YIG -         OUT
 CAL. MODE -      PULSE
CORRECTION FACTORS -
 RF LINE ATTEN. - *
 RF LINE CORR. - *
 RECEIVER DESENS. - *
AIRCRAFT DATA -
 RANGE - 10 N.M.
 ALTITUDE - 1900 FT.
 BANK ANGLE - 1 DEG.
SHIP DATA -
 SHIP HEADING - 285 MAG.
EMITTER
 NO. -          1
 MODE -    RADIATE
 PW - 2.0 MICROSEC.
 PRF - 500 HZ.
 FREQ. - 2900.1000 GHZ.
 ANT. ELEV. - 5 DEG.
 ANT. AZIMUTH - 90 DEG.
 ANT. SCAN RATE - *
 ANT. GAIN - 30.0 DB
COMMENTS - EMPASS ANTENNA
 LEFT-HAND CIRCULAR
 POLARIZATION.
MAXIMUM DBM = -17.12
 AT 367 DEGREES

* INFORMATION INAPPLICABLE OR NOT AVAILABLE
```

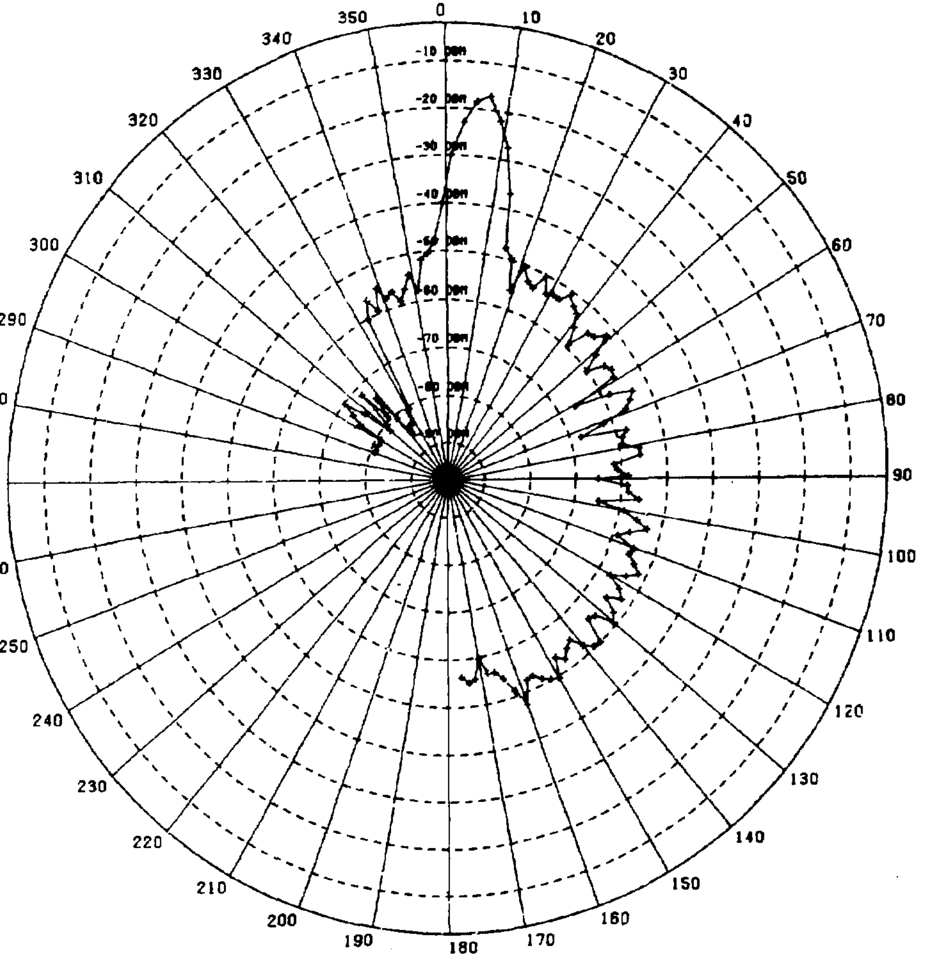


Figure 17. Sample Antenna Pattern (Polar)

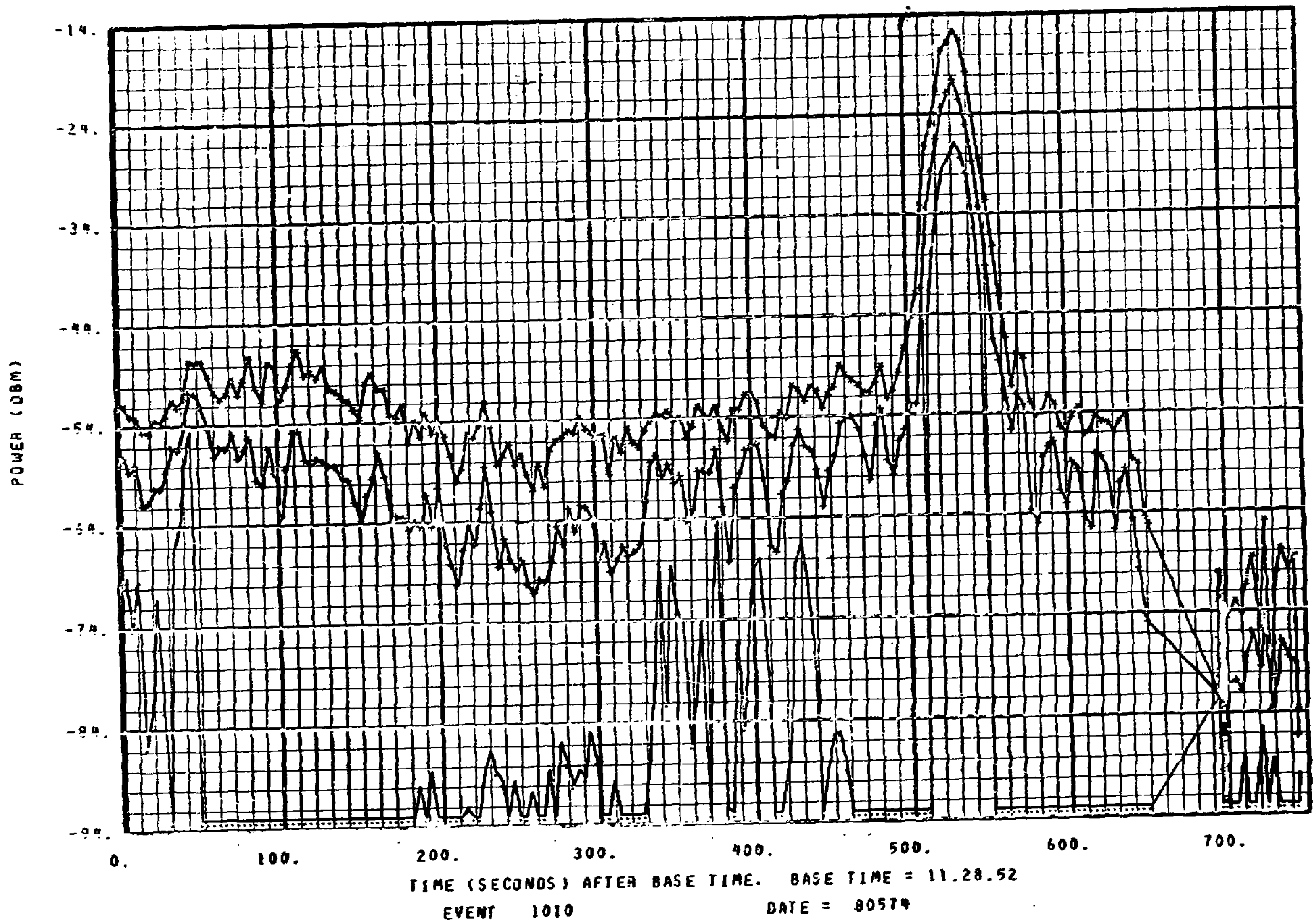


Figure 18. Sample Time vs Power Plot
(*, maximum; +, average; ·, minimum)

```
EVENT NUMBER = 1010,    START TIME = 11.28.51,  END TIME = 11.41.26,    ELAPSED TIME =     755.05 SECONDS.
 ENDING DATA LOST

                 DDM SELECTED,

NUMBER OF ACCEPTED ITEMS =     2761, NUMBER OF POSSIBLE  ITEMS =  3010, NUMBER OF ITEMS WITHOUT PULSES =    228
NUMBER OF PULSES =  335677,  NUMBER OF TIMES MISSED PULSE FLAG SET =    15389

   PARAMETER                          MEAN    MAXIMUM    TIME OF MAX    MINIMUM    TIME OF MIN
   AMPLITUDE (VOLTS)                  1.40       3.86     11.37.42        0.00       11.41.13
   DA AMPLITUDE (VOLTS)               0.00       0.00     11.41.27        0.00       11.41.27
   PRI (MICROSECONDS)              2146.04  606122.24     11.39.53         .32       11.41.15
   PW (MICROSECONDS)                  5.78     457.06     11.30.40        0.03       11.41.21
   TIME BETWEEN SAMPLES (SECONDS)  .002068    .573710     11.40.43     .000030       11.31.17

   NAV PARAMETER             MAXIMUM    TIME OF MAX    MINIMUM    TIME OF MIN      START       STOP
   LATITUDE -DEGREES           13.45     11.37.45        18.10      11.28.51      18.16      13.36
   LONGITUDE -DEGREES         -65.57     11.33. 0       -65.93      11.41.22     -65.72     -65.93
   EAST VELOCITY -KNOTS       197.22     11.25.51      -211.93      11.37.41     197.22     -63.81
   NORTH VELOCITY-KNOTS       211.53     11.33.19      -182.72      11.41.26      13.60    -182.72
   TRACK ANGLE-DEGREES         56.33     11.25.51      -159.91      11.41.25      56.33    -159.91
   INERTIAL HEADING-DEG        69.71     11.26.51      -162.66      11.41.26      89.71    -162.55
   PITCH-DEGREES                4.35     11.41.20         -.18      11.40.43       1.94       2.59
   ROLL-DEGREES                  .53     11.32.42       -12.49      11.41.23      -3.73     -11.09
   TACAN BEARING-DEG.         180.34     11.23.52       179.96      11.20.51     179.96     179.96
   TACAN RANGE-N. MILES       403.53     11.25.51       409.60      11.25.51     409.63     409.63
   COMPASS HEADING-DEG.       164.54     11.23.51       164.04      11.28.51     164.84     164.84
   ALTITUDE -FEET           33634.99     11.33. 9     30654.37      11.28.53   30674.98   30674.98
  NUMBER OF NAVIGATION ITEMS =  3060

                                   FREQUENCY                   COMPUTER  RF SYSTEM  DF SYSTEM                                                  ATTENUATION
STATUS    RECEIVER   ANTENNA       BAND       POLARIZE  POLARIZE  COMPUTER   COMPUTER   ANALYZER      TWT         YIG          LINE  EQUAL  ZE?
START       HIGH       WING          5        VERTICAL     OFF       OFF        OFF        OFF         OFF         OFF            0            ?
STOP        NONE       NONE          0          RHC        OFF       OFF        OFF        OFF         OFF         OFF            0           21
CHANGES     335        335         337          337         4         0          0          0           0           6             0          333
  NUMBER OF STATUS ITEMS =  3060

YIG CHANGED AT TIME  41534.38  41594.33  41957.33  41957.62  42008.83  42089.08

HFR1 FREQUENCY (KHZ) =       2621+200.      HFR2 FREQUENCY (KHZ) =       26214200.

               NHDDR93  ////END OF LIST ON LP 76 ////
```

Figure 19. Sample Statistical Summary

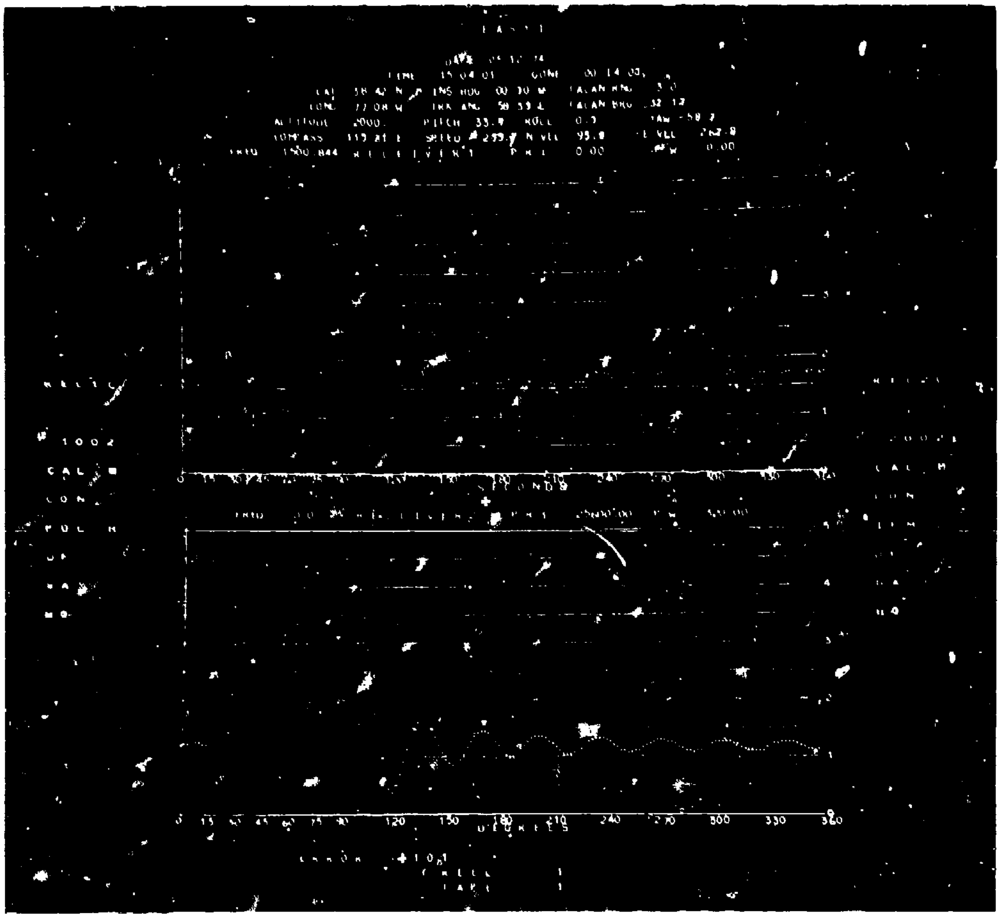


Figure 23. General Purpose Display

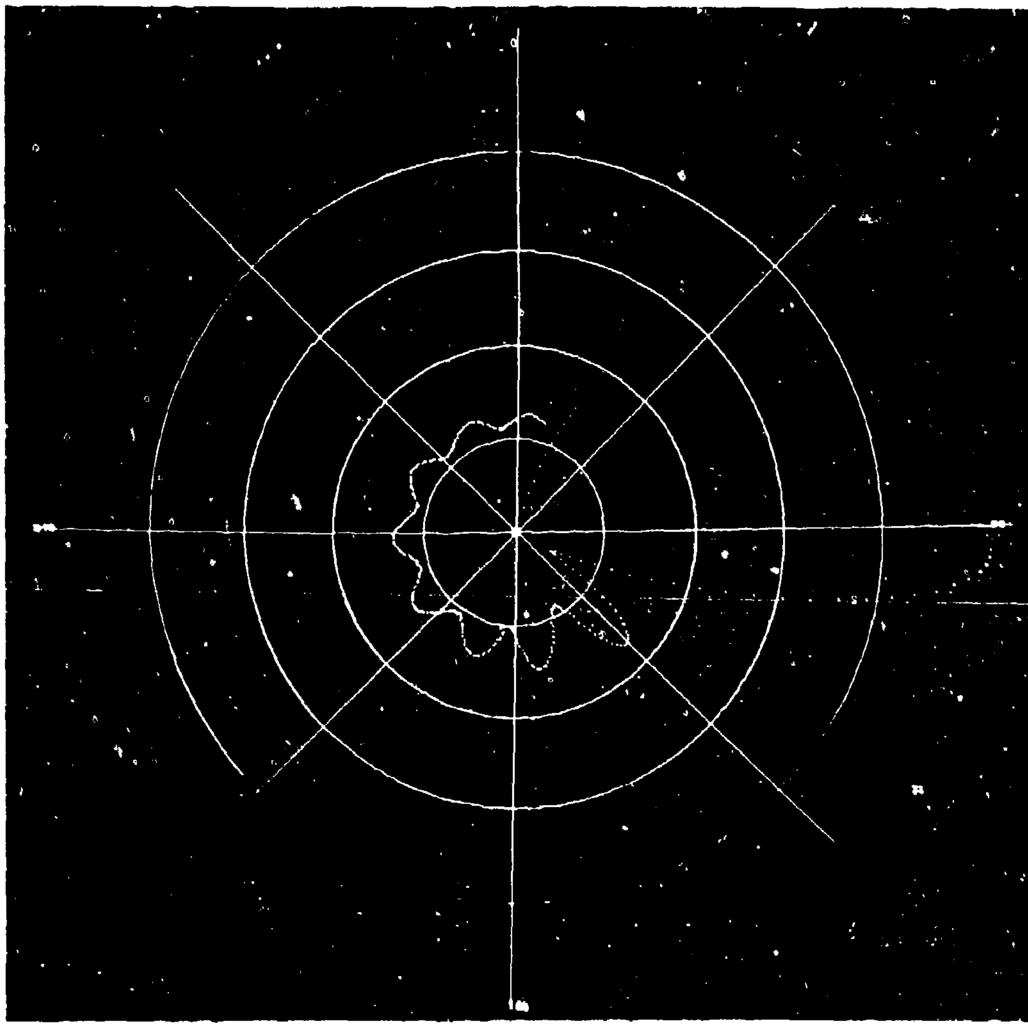


Figure 21. Special Display (Polar)

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A digital system developed to support the Electromagnetic Performance of Air and Ship Systems (EMPASS) Project at NSWC/DL is reported. The airborne system consists of RF receivers and antennas with special relays and interface units which allow a UNIVAC 1830A computer to interrogate and control them. Aircraft position, RF signal, and system status measurements are recorded digitally on magnetic tape while operator displays are provided for some immediate data analysis and system monitoring. The

software for this data acquisition system was designed and developed at NSWC/DL and is currently being used on test and measurement missions of the EMPASS aircraft.